

**Annual Productivity Report**  
**Grant No. N00014-95-1-1211**  
**1 October 1995 to 30 September 1996**

Grant: N00014-95-1-1211

Title: Sediment Penetration of Underwater Mammalian Sonar Signals

Program: ONR/ARPA Research to Replicate Biological Sonars

Principal Investigator: Nicholas P. Chotiros

Institution: Applied Research Laboratories, The University of Texas at Austin

**Overview**

The objective is characterization of buried target detection by underwater mammalian sonars. To this end, a collaboration has been formed between Applied Research Laboratories, The University of Texas at Austin (ARL:UT) and Naval Command, Control and Ocean Surveillance Center (NRaD), San Diego. ARL:UT brings expertise in the modeling of sediment acoustics, and signal processing. NRaD possesses extensive experience in the training of mammals to locate buried objects, as well as the facilities for experimental investigation. Mammalian sonar pulses will be recorded in the course of a buried object search exercise, to observe their evolution from the initial search phase, through detection, location and classification phases. A preliminary set of recordings was made in March 1996 to measure certain characteristics of the mammalian sonar signals. Progress has been made in the construction of the recording apparatus, which must not distract the mammals. The first set of measurements with the full system is planned for August 1996. In parallel, a theoretical model is being developed to simulate the penetration of sound pulses into the sediment. Initial results indicate the possibility of one incident pulse producing two pressure pulses in the sediment. Through both modeling and experimentation, the performance envelope of the mammalian sonar will

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be estimated. Finally, through analysis of the spatial and temporal characteristics of the signals, attempts will be made to deduce the methods used by mammals to achieve target detection and classification.

### **Accomplishments**

The project plan has three components: (1) direct measurement and analysis of acoustic signals incident on buried targets; (2) construction of acoustic penetration and target scattering model for mammalian sonars; and (3) deduction of mammalian sonar methods through reproduction of target insonification processes. Parts (1) and (2) are in progress. Accomplishments to date are as follows:

#### **(1) Direct measurement of signals incident on buried targets**

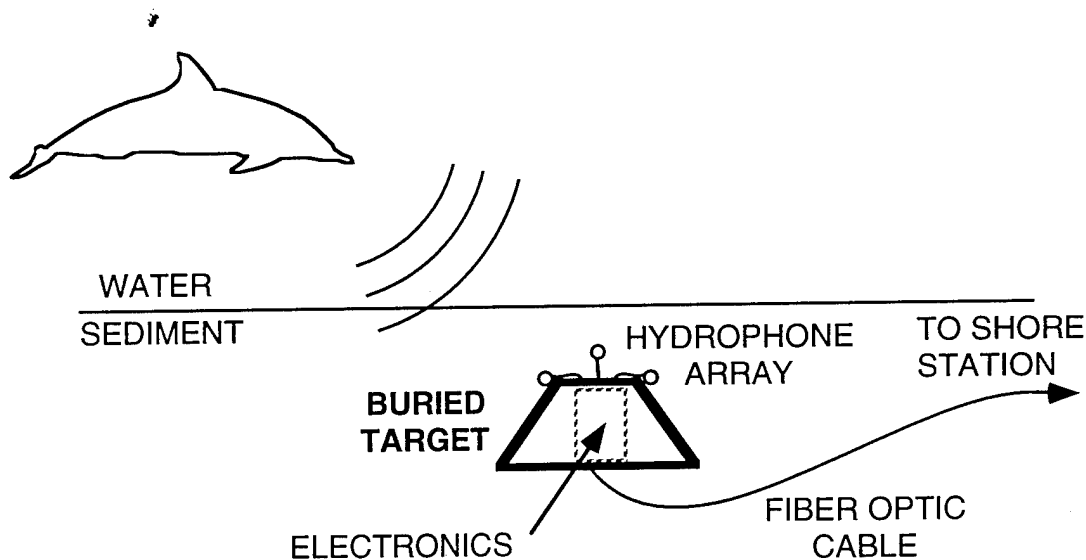
##### **Purpose:**

The ability of certain mammals to locate and classify objects buried in sediment has been documented but their methods are not known. The first step towards understanding their methods is to record the signals that mammals use to search for buried targets in situ, and observe their evolution from the initial search phase, through the detection, location and classification phases.

##### **Equipment:**

Acoustic receivers have been designed for placement on and around a buried object to record the incident sonar signals from a mammal searching for the object. The received signals will be digitized and transmitted via fiber optic cable to a shore station for processing and storage. To minimize the possibility of distracting the mammal, the buried hydrophones were designed to be as small and unobtrusive as possible. The underwater unit was designed to fit inside the buried object. The fiber optic cable, a quarter inch in diameter, will

also be buried and routed away from the buried object. The experiment is illustrated in Fig. 1. Data will be collected and processed on a shore based workstation. The construction of the equipment is expected to be complete in August 1996, and experiments will commence immediately thereafter. The experiment will be conducted in collaboration with NRaD, San Diego, who will provide diver support and mammals under training to search for the buried objects. The buried objects will be various mine cases, including the Manta mine.



**Figure 1.**

**Direct measurement of acoustic signals incident on buried targets.**

Preliminary measurements:

A preliminary set of measurements were taken to determine a number of unknowns, including type and density of acoustic pulses that are likely to be

encountered, and the duration of the search process. A single hydrophone was placed near a buried target and cabled to a support boat. Signals from a mammal searching for the target were recorded as the mammal approached the target and dropped a marker as part of its training exercise. The experiment was done at NRaD, San Diego, with full NRaD support and NRaD mammals under training. It typically took between 20 and 30 seconds, from the time the command was given to start the search until the mammal drops the marker near the target. The signals were found to contain pulse trains and chirps. An example of the recorded signals is shown in Fig. 2. Signals from 3 seconds before impact of the target marker are shown with marker impact shown as  $t=0$ . A number of pulse trains are discernible. Each pulse train consisted of several tens of pulses. It appears that the pulse repetition period becomes shorter as the mammal approaches the target, ranging from over 20 ms at 2 seconds before impact to about 1 ms just before impact. How these pulse trains are used is not known. There is a short period of relative silence before a final burst just before the marker impact. Then there is a final pulse train in which the repetition period is increasing, indicating that the mammal is pulling away.

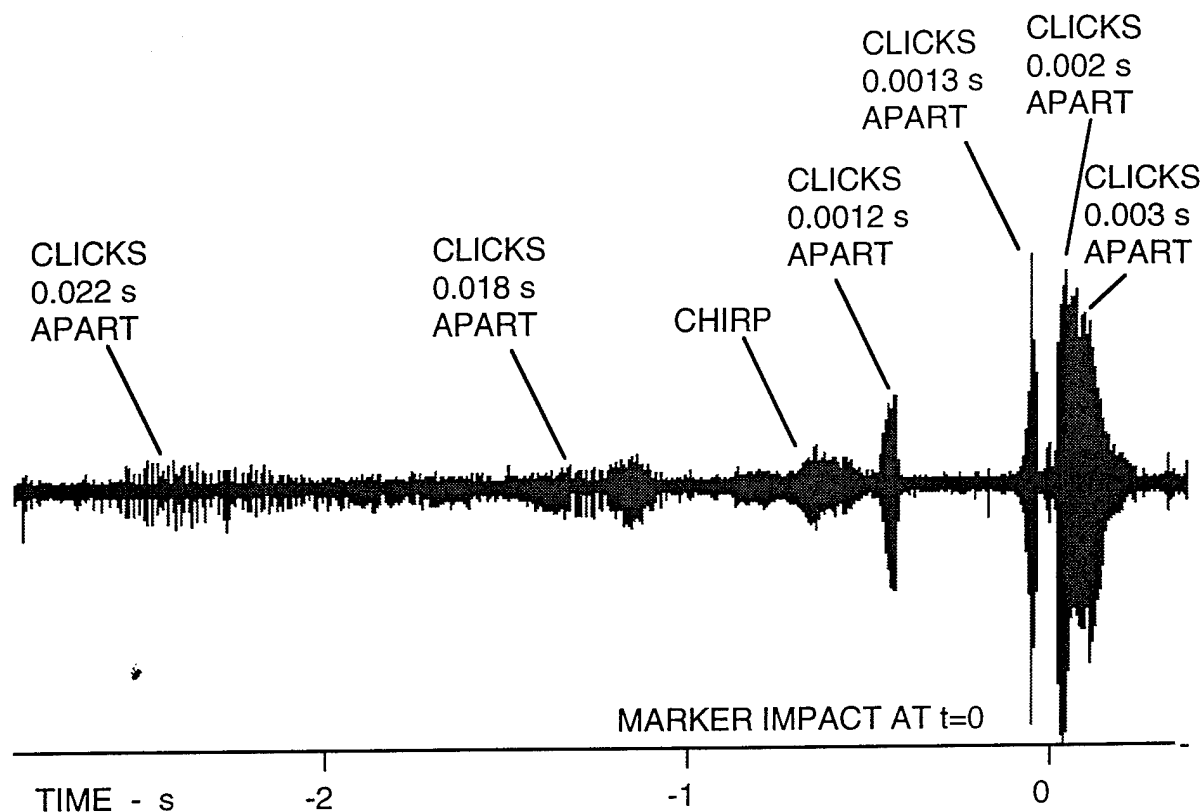


Figure 2.

Example of sonar signals recorded at a buried target.

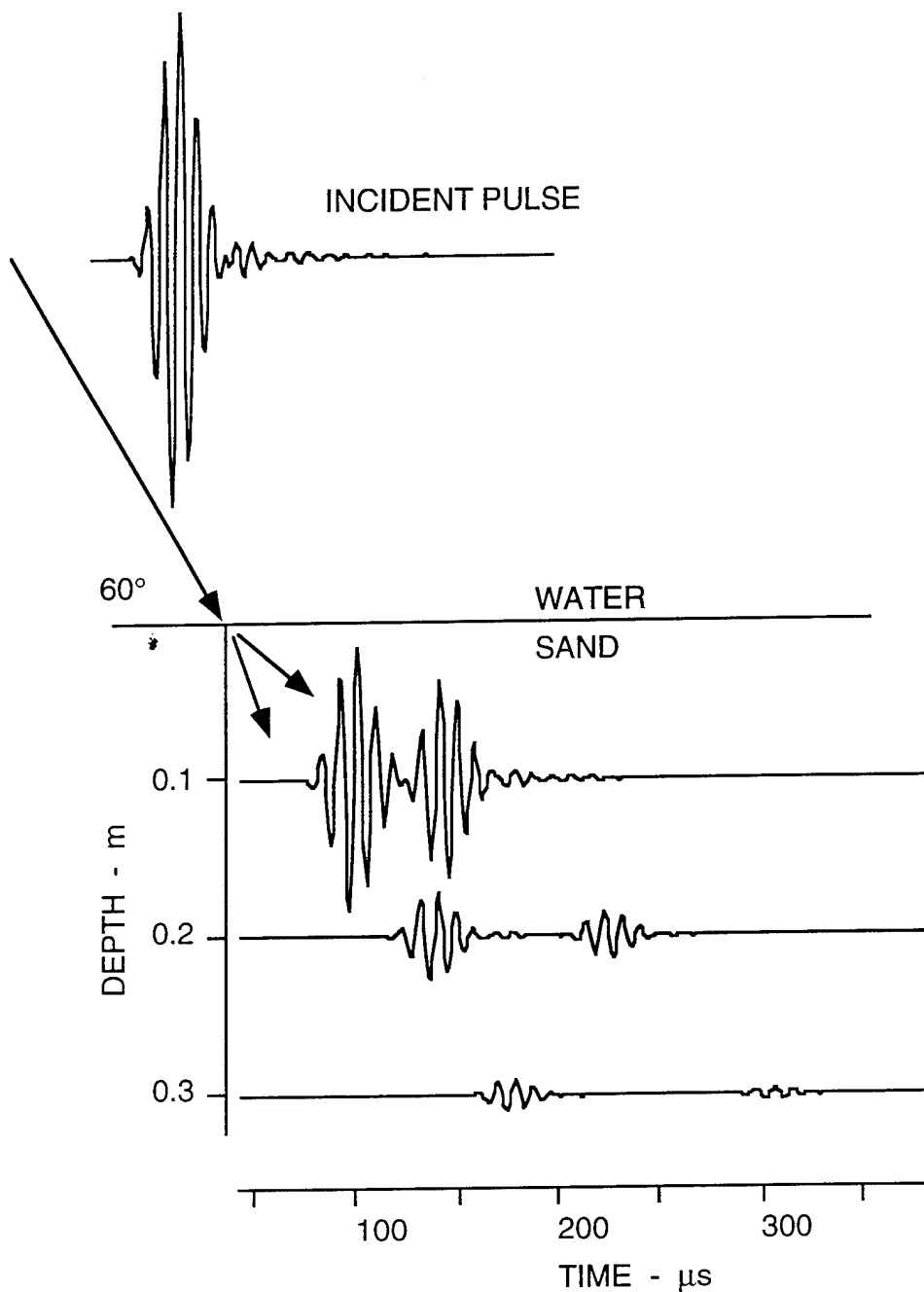
## (2) Sediment penetration for mammalian sonars

### Purpose:

The sound penetration and backscatter at the mammalian sonar frequencies will be modeled to obtain estimates of the performance envelope of the mammalian sonar and compared with observed performance. The results will contribute to the design of wideband systems that could potentially match or exceed the performance of mammalian systems.

#### Sediment penetration modeling:

A pulse penetration model has been constructed to compute the penetration of mammalian sonar pulses, based on Biot's theory of acoustic propagation in water-saturated porous media. This approach is general enough to model a wide variety of sediments, and has been found particularly suitable for sandy sediments[1]. Using a "dolphin-like" pulse supplied by Au[2], sediment acoustic pulses were computed. An example is shown in Fig. 3, of a plane wave pulse in a sandy sediment at various depths. The model shows that a single incident pulse at a grazing angle of  $60^\circ$  generates two sediment pressure pulses, corresponding to the Biot fast and slow waves. What effect this will have on target detection and classification is not known at present.



**Figure 3**  
Incident dolphin-like pulse and computed pressure signals in a sandy sediment at various depths.

## **Productivity Report**

### **Number of ONR supported publications:**

Papers published in refereed journals: 0

Papers accepted for publication in refereed journals: 0

Papers or reports in non-refereed journals: 2

Nicholas P. Chotiros, Adrienne Mautner, Model of shear wave speed in water saturated sand, Engineering Mechanics, Proc. 11th Conference, pp. 804 - 807, May 19 - 22, 1996

Dennis Yelton, Morris Stern, Nicholas P. Chotiros, New Multiple Scatter Model of the Ocean Sediment, Final Report, Grant N00014-94-1-0438. Technical Report No. ARL-TR-95-26, Applied Research Laboratories, University of Texas at Austin, 1995

Books or book chapters published: 1

N. P. Chotiros, Inversion and sandy ocean sediments. Full Field Inversion Methods in Ocean and Seismic Acoustics, Diachok, Caiti, Gerstoft, Schmidt Editors, ISBN0-7923-3459-0, Kluwer Academic Press, 1995

Books or book chapters in press: 0

Number of ONR supported patents/inventions filed or granted: 0

Number of presentations:

Invited: 1

N. P. Chotiros, Acoustic penetration of ocean sediments in the context of Biot's theory. J. Acoust. Soc. Am. 99(4) Pt. 2, 2474, April 1996

Contributed: 5

Nicholas P. Chotiros, Adrienne Mautner, Åge Kristensen, Oddbjorn Bergem, and Arne Løvik. Acoustic bottom penetration in a shallow site from a parametric projector. J. Acoust. Soc. Am. 98(5), Pt. 2, 2953, November 1995

R. A. Altenburg, N. P. Chotiros, Measurements of the acoustic (200 kHz) backscatter from a carbonate sediment at low grazing angles. J. Acoust. Soc. Am. 98(5), Pt. 2, 2987, November 1995

F. A. Boyle, N. P. Chotiros, Nonlinear acoustic scattering from trapped gas bubbles in sandy sediments. J. Acoust. Soc. Am. 98(5), Pt. 2, 2978, November 1995

N. P. Chotiros, Adrienne Mautner. Model of shear wave speed in water saturated sand. Engineering Mechanics, Proc. 11th Conference, pp. 804 - 807, May 19 - 22, 1996

Dennis Yelton, N. P. Chotiros, Angular variation in the simulated refraction and scattering properties of granular poroelastic ocean sediments. J. Acoust. Soc. Am. 99(4) Pt. 2, 2500, April 1996

Trainee data:

	TOTAL	FEMALE	MALE	MINORITY	NON-US
No. of graduate students	3	0	3	1	0
No. of Post doctorals	0				
No. of undergraduates	5	3	2	1	0

Number, cost and description of equipment items costing more than \$1000 that were purchased on your ONR grant:

Description	QTY	Cost
103 composite PZT-4, shore D80 sonopanel	2	\$4,400

Honors to PI or members of PI's research group

Member of Underwater Acoustics Technical Committee, Acoustical Society of America

Member of Panel on Undersea Warfare, Naval Studies Board Study on Technology of Future Naval Forces

#### Transitions:

Elements of model[3] for acoustic propagation in ocean sediments have been incorporated into a new bottom backscattering model, called BOGGART, currently undergoing tests.

[1] N. P. Chotiros, Biot model of sound propagation in water-saturated sand. J. Acoust. Soc. Am. 97(1), 199-214, January 1995

[2] W. Au, private communication, 1995.

[3] N. P. Chotiros, Biot model of sound propagation in water-saturated sand. J. Acoust. Soc. Am. 97(1), 199-214, January 1995

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